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14. ABSTRACT <p>The Geophysics Fluid Dynamics (GFD) program consists of a summer study school of ten weeks duration each summer. The primary aim of the program is to visit a different specific area of GFD each summer, review fundamentals, and to help each other to conduct original research. Participants are approximately ten graduate student fellows, visiting graduate students and both visiting and returning scientists. The first two weeks consist of principal lectures in the summer's topic conducted by an expert in that area. Lectures by staff and visitors follow at a rate of roughly one or two per day for the next six weeks. In the last week, the fellows present results of a project and a written report. The fellows also write up the principal lectures. All are collected in a volume and on the web.</p>					
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## **Interdisciplinary Research Programs in Geophysical Fluid Dynamics**

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<http://www.whoi.edu/education/gfd>

### **LONG-TERM GOALS**

The long-term goals are to train new scientists to conduct research, and to enhance the abilities of experienced research workers in geophysical fluid dynamics. This field is fundamental to the field of numerical forecasting of ocean, atmosphere and environment.

### **OBJECTIVES**

To help graduate students formulate and tackle innovative research problems in GFD. To promote an exchange of knowledge and ideas between investigators in the different scientific disciplines that deal with the dynamics of stratified fluids, rotating fluids, fluid with phase changes and non-Newtonian fluids. To formulate tractable, important problems which are presently at the fringe of our understanding in the field of Geophysical Fluid Dynamics. To serve as a clearing-house for the mathematical, experimental and computational techniques which serve astrophysics, climate science, geodynamics, meteorology and oceanography.

### **APPROACH**

We conduct a summer study school of ten weeks duration each summer. The participants are graduate student Fellows, visiting graduate students and visiting scientists. The first two weeks consist of ten principal lectures in the summer's topic conducted by an expert in that area. Lectures by associated participants follow at a rate of roughly one or two per day for the remaining weeks except for the last week, when student Fellows present their results. About 10 graduate students are admitted as Fellows, selected from a pool of applicants from many disciplines who are in their second to fourth year of graduate school. Fellows receive a stipend for the full ten weeks. A Fellow conducts a research project

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under the guidance of the staff, provides a written project report, and orally present results in the tenth week. The Fellows also prepare note of the principal lectures. Several other graduate students visit for shorter periods to listen to lectures and interact with the staff. The staff and faculty (comprised of all of the visiting scientists) are continually renewed throughout the summer, although there is a core faculty who remain for the entire summer. Most of these participants receive partial travel support from the program, but some participate for free. The lecture notes and the written report of the Fellows' projects are contained in a volume that is distributed in print form and is available on the GFD website.

## **TASKS COMPLETED**

Two summers are completed in 2004 and 2005. After the principal lectures, participants and visitors who have studied turbulence, convection, and instability in numerous geophysical situations with application to the ocean, the earth's atmosphere and planetary circulation made numerous contributions with approximately 40 additional lectures. Fellow's lectures were given in the final week.

The theme was Tides for the year 2004 (45th year of the program). The principal lectures were by Chris Garrett of the University of Victoria, Canada, and Myrl Hendershot of Scripps Institution of Oceanography at the University of California, San Diego. Weeks 4-6 had special topics in oceanic tides, planetary tides, and tides in astrophysics. Co-directors were Neil Balmforth of the University of British Columbia and Stefan Llewellyn Smith of the University of California, San Diego.

The 2004 fellows, their main interest, and their University affiliation are:

1. Josefina Arraut, a Meteorologist from the Brazilian Institute for Space Research. "Rossby Wave Scattering between Homogeneous Media".
2. Vineet Birman, an Engineer from the University of California, Santa Barbara. "Non-Normal Convection".
3. Visweswaran Nageswaran, a mathematician from the University of Massachusetts, Amherst, "Parametric Instability of Internal Waves with Rotation".
4. Lisa Neef, a physicist from the University of Toronto. "Resonant Triads of Tidally-Forced Internal Gravity Waves".
5. Anja Slim, an Applied Mathematician from the University of Cambridge. "Exotic Gravity Currents".
6. Yara Toledo, a Civil Engineer from The Technion University in Israel. "Resonant Triads of Tidally-Forced Internal Gravity Waves".
7. David Vener, and Applied Mathematician from the Massachusetts Institute of Technology. "Two-Dimensional Vortex Shedding from a Corner".
8. Danielle Wain, a Civil Engineer from the University of Illinois. "Laboratory Experiments on the Effect of Baroclinic Eddies on a Dense Plume in a Rotating Stratified Fluid".
9. Marshall Ward, a Geophysical Fluid Dynamicist from Florida State University. "Double Diffusive Gravity Currents under Rotation".
10. Eleanor Williams, a Physical Oceanographer from the University of Washington. "Convection in a Fluid Loop".

The 2005 lecture topic was "fast and slow time scales". Principal lecturers were Joseph B. Keller (Stanford), George C. Papanicolaou (Stanford), and Eric Vanden-Eijnden (Courant Institute).

Two photographs one of a formal lecture and one of a spontaneous lecture, are shown in figure 1. Charles Doering of the University of Michigan, and Oliver Buhler of the Courant Institute at New York University were co-directors.

The 2005 Fellows, their University affiliation, and their project title are:

1. Benjamin Akers, University of Wisconsin-Madison, Shallow water flows through a contraction.
2. Tiffany Shaw, University of Toronto, Bounds on multiscale mixing efficiency.
3. Walter Pauls, University of Nice, Diffusion processes in cellular flow.
4. John Rudge, University of Cambridge, Scattering past a cylinder with weak circulation.
5. Khachik Sargsyan, University of Michigan, Fluctuations in chemical systems in the large volume regime.
6. Ravi Srinivasan, Brown University, Simple models with cascade of energy and anomalous dissipation.
7. Inga Koszalka, Politecnico di Torino, The vibrating pendulum and stratified fluids.
8. Alexander Hasha, New York University, A search for baroclinic structures.
9. Arghir Dani Zarnescu, University of Chicago, Intermittency in simple models for turbulent transport.
10. Marcus Roper, DEAS, Harvard University, Internal wave breaking and mixing in the deep ocean.
11. Aya Tanabe, Imperial College of London, Laboratory experiments on mesoscale vortices colliding with multiple islands.

## RESULTS

The Principal Lectures and Fellows' reports are the tangible results. They are available as a technical report and on the web. A number of published papers typically result from the program, many are listed on the web page.

## IMPACT FOR SCIENCE

Many staff, fellows and visitors express their enthusiasm at the end of each summer. We conducted a survey 5 years ago for the past 20 years of Fellows as part of the celebration of the 40<sup>th</sup> year of the program. About 80% of the remarks were highly complimentary. A few of the roughly 50 responses are given here:

"The GFD program is a great educational experience which introduces many talented future scientists to our field. We should make every effort to make sure it continues for many generations of new scientists. Adding more visiting lecturers can be beneficial to all."

"The GFD faculty was, taken as a group, as good as or better than the best department anywhere. It was a real treat to be a student/Fellow of this group."

"The most valuable lesson for me was watching this accomplished group 'do science'. I learned more from interacting with them, and watching/listening to them interact with one another and with other Fellows than from any specific problem or piece of research."

Some Fellows had serious suggestions for improvement, such as:

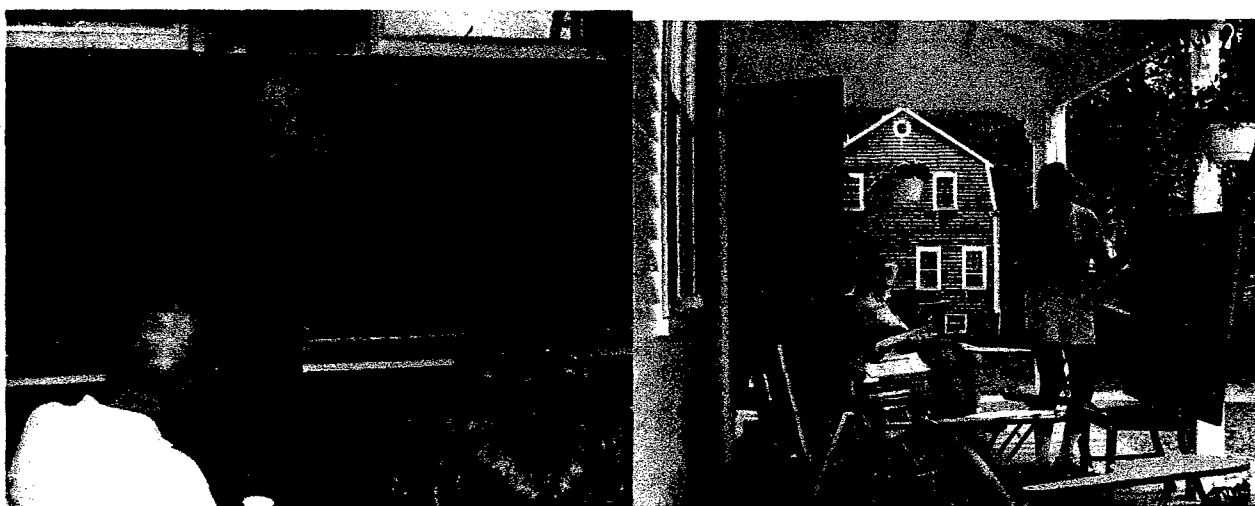
"I chose the wrong project with the wrong advisor. I didn't get much out of the summer. But, in a different situation, I definitely would have."

Because of the last remark, the staff increasingly pays attention to each fellow and works to make each fellow achieve a good project in conjunction with a suitable advisor. The Dean's office also has the Fellows evaluate the program, and many comments are similar to those given here.

## RELATIONSHIPS TO OTHER PROGRAMS

We estimate that typically 20-50% of the student projects become included in their thesis or postdoctoral work and/or result in publications. The program does not follow the Fellows' research after the summer is finished although individual staff members often remain involved with the Fellows' continuation of their projects past the end of the summer. All staff members are active research workers, so numerous related projects exist.

## FIGURES/PICTURES



*Figure 1. Two photographs of Joseph Keller at the blackboard. On the left, during a talk in the lecture hall in Walsh Cottage. On the right is a spontaneous lecture on the porch of Walsh Cottage [In the right panel, three people look at a temporary blackboard stuck up on a chair. An animated Keller, in shorts, is emphasizing a point to the listeners]*

## REFERENCES

A number of features of the program are listed on the web at <http://www.who.edu/gfd>. This includes a list of past Fellows, the titles of the lectures, a list of participating scientists, a yearly newsletter, and recent past volumes (containing lecture notes and the fellows' project reports).